STUDIES OF MARBLED MURRELETS IN MARINE HABITATS, DURING 1990

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I. EARLY BREEDING SEASON DISTRIBUTION OF MARBLED MURRELETS

keywords: Marbled Murrelet, British Columbia, distribution

Abstract: A shipboard survey for Marbled Murrelets (Brachyramphus marmoratus) along the central coast of British Columbia revealed considerable variation in density of birds on the water. Areas near Cape Caution and Aristazabal Island had very sparse populations while Mussel and Kynoch inlets had very high numbers. The sheltered inlets were particularly important eventhough there do not appear to be any stands of typical old-growth forest. Overall, densities correlated negatively with sea surface salinity and positively with the density of Mew Gulls (Larus canus).

Résumé: Un recensement par bateau d'alques marbrés (Brachyramphus marmoratus) le long de la côte centrale de Colombie Britannique a indiqué une variation considérable dans la densité d'oiseaux sur l'eau. Les régions de Cape Caution et de l'île Aristazabal furent utilisées par faibles concentrations d'oiseaux tandis que les anses Mussel et Kynoch furent utilisées par des nombres importants d'oiseaux. Les anses abritées apparaissent particulèrement importantes, malgré l'absence de forêts anciennes. Les densités totales sont correlées négativement avec la salinité à la surface de l'ocean et positivement avec la densité de goélands cendrés (Larus canus).

INTRODUCTION

Although Marbled Murrelets (Brachyramphus marmoratus) are one of the few birds that use coastal inlets in summer, little is known about their abundance or distribution (Campbell et al. 1990). Their habitat preferences are not understood and they have not been the subject of large-scale population surveys. The most information on the distribution of the species is contained in site record cards collected by the Royal British Columbia Museum. Estimates of the bird's status in British Columbia, based on those haphazard data are strongly dependent on the distribution of observers (Campbell et al 1990, Rodway 1990). The cards also vary in quality and accuracy but they identify large concentrations of murrelets near Athlone and Price islands and Higgins Pass on the central mainland coast. In 1989, Rick Burns and Lynn Prestash (volunteer Ecological Reserve Wardens) reported several hundred murrelets in Mussel Inlet. When they offered transport to the area in the spring of 1990, we decided to survey the area. This report describes counts of Marbled Murrelets made during the subsequent cruise of the F/V Pacific Provider along various inlets and channels between Cape Caution and Prince Rupert.

The survey objectives included: a) developing an appropriate survey design for Marbled Murrelets; b) testing the relationship between observed densities of birds and simple habitat parameters such as sea surface temperature and salinity, channel width, and channel depth; c) comparing bird-use among a sample of inlets.

METHODS

Study area

The cruise line followed the mainland coast from the Storm Islands (51° 03' N, 127° 40' W), south of Cape Caution, to Prince Rupert (54° 20' N, 130° 20' W) (Fig. 1). This is an area of numerous small islands and deep fiords mostly in the Hecate Depression and Hecate Lowlands ecosections of the Continental Shelf Ecoregion (Campbell et al. 1990 p. 67). The forest cover consists of Douglas fir (Pseudotsuga menziesii), western redcedar (Thuja plicata), and western hemlock (Tsuga heterophylla). Extensive shallow areas (e.g. Aranzazu and Moody banks) and large offshore banks (e.g. Otter and Goose banks) lie seaward of the coastal islands. The surface salinity is heavily influenced by freshwater runoff from glaciers, snowpack, and heavy rains that characterize the coastal mountains (Thomson 1984, Campbell et al. 1990). There are few settlements and human impact in the inlets is largely limited to a few hand-logging operations.

Survey design

We scheduled the cruise for two weeks (15 to 30 May) at the beginning of the breeding season when we expected most of the murrelets to be on the water in pairs (Campbell et al. 1990). The survey design was based on the recommendations for small boats by Gould and Forsell (1989) and the PIROP protocol (Brown et al. 1975). Each observer recorded observations during 10 minute periods on one side of the vessel using 10X wide-angle binoculars. Surveys were conducted at all times of day. Important land marks and chart features were noted so that the distance travelled could be calculated.

We collected water samples from the surface, while the boat was underway, in a 1.0 L bucket and measured the sea surface salinity (SSS) with an American Optical refractometer to 0.5 ppm. Sea surface temperature (SST) was measured with a thermometer in 1° C gradations.

We converted all observations to densities (birds/km^2) based on the distance between major landmarks and the distance to shore during that leg of the survey. Densities, chart data (channel depth and channel width), and water characteristics (SST and SSS) were compared by the linear repression program in LOTUS.

RESULTS

Survey technique

In calm water, the vessel made 7 to 8 knots but speed varied depending on the currents because the engine speed was constant. We attempted to keep a constant distance to shore (monitored on the boat's radar) but the cruise line was often determined by safety factors and the requirements of seamanship. On the outer coast, distance to shore beside clusters of islets varied from 1 to 5 km because of dangerous shallows. The inlets were much deeper and usually had a simple shoreline that was kept about 0.5 km off starboard.

Bird distribution and densities

The survey covered 640 km of coastline during two weeks of clear, sunny weather. We counted 3099 fish-eating birds including 1059 Marbled Murrelets (Table 1). The murrelets were not evenly distributed along the cruise line but were highly concentrated in Milbanke Sound and adjacent inlets and channels. Other fish-eating birds were concentrated in the same area but not necessarily in the same habitats. Principe and Petrel channels had very small numbers of birds.

The marine avifauna along the cruise line was not very diverse. Only 14 species of fish-eating birds were common (Table

1) while a few scoters and Brant (Branta bernicla) occurred locally. At the heads of inlets there were a few late-migrant Barrow's Goldeneye (Bucephala clangula), a few pairs of Harlequin Ducks (Histrionicus histrionicus) and Common Mergansers (Mergus merganser), and small flocks of Mew Gulls (Larus canus) or migrant Bonaparte Gulls (L. philadelphia). Along stretches of open coast on 15 and 16 May, we saw large numbers of migrant Pacific Loons (Gavia pacifica) and flocks of Semipalmated Plovers (Charadrius semipalmatus) and small sandpipers.

Only one large flock of Marbled Murrelets was seen. Between 2000 and 2100 hrs on 16 and 17 May, 100 and 81 murrelets, respectively, gathered in Goose Anchorage (Goose Group). About half of the flock were not fully moulted from winter plummage and only a 25 percent occurred in pairs.

Elsewhere, most murrelets occurred as singles and pairs or occasionally in small groups. This is obvious from Fig. 2, which shows totals for 10 min survey units. Most units with murrelets contained only 1 or 2 birds. The median density was 1.3 murrelets/km^2 and densities exceeded 2 per km^2 on only 7 of 20 survey segments (Fig. 1):

(A) Cape Caution (0.0 murrelets/km^2, 2 to 5 km offshore). This is a stretch of exposed coast off a low-lying and boggy part of the mainland. Much of the shore is less than 15 m above the tideline. There were many fish-eating birds but few murrelets. We were as much as 5 km offshore at times, however, and murrelets may have been present closer to land.

(B) Fitzhugh Sound (0.2 murrelets/km^2, 0.5 km offshore). This broad channel is a major shipping route and forms the entrance to the inside passage. The site record cards indicate that few birders have seen murrelets from the ferries and we saw few birds eventhough we were much closer both to the water surface and to shore (0.5 km).

(C) Queens Sound (0.1 murrelets/km^2, > 5 km offshore). This leg included another stretch of open coast where we were often more than 5 km offshore. The water is shallow (about 50 fathoms), however, and we passed through large flocks of auklets, murres, and Pacific Loons.

While anchored in the Goose Group, we observed a lone sea otter (Enhydra lutris) on the west side of Swan Island.

(D) Milbanke Sound (4.2 murrelets/km^2, 0.5 km offshore), from the Goose Group to the mouth of Mathieson Channel. This segment contained many fish-eating birds: Rhinoceros Auklets (Cerorhinca monocerata), Cassin's Auklets (Ptychoramphus aleuticus), Common Murres (Uria aalge), and the only three Ancient Murrelets (Synthliboramphus antiquus) seen on the cruise. West of the McMullin Islands we saw a flock of more than 130 Bald Eagles

(Haliaeetus leucocephalus) preying on a ball of fish at the surface.

(E) Mathieson Channel (0.9 murrelets/km^2, 0.5 km offshore). This channel leads north to Kynoch and Mussel Inlets. It is steep-sided with few sources of fresh water and few small bays. Birds of any species were scarce but from Symonds Point to Kynoch Inlet, we saw 37 Dall's Porpoise (Phocoenoides dalli) in pairs and small groups.

(F) Kynoch Inlet (3.1 murrelets/km^2, 0.4 km offshore). This fiord is bounded by steep walls and has little estuarine development except at its head. Along its course, several streams enter as waterfalls. Murrelets occurred in scattered singles and pairs and outnumbered all other species. This was the only place that we saw 2 murrelets driving a school of Pacific sand lance (Ammodytes hexapterus) to the surface.

(G) Mussel Inlet (6.1 murrelets/km^2, 0.3 km offshore). This is another steep-walled fiord very similar to Kynoch Inlet but it has a more complex shape. Parts of it receive very little sun and, when we visited, again, at the end of June, we found large mounds of snow at the feet of cliffs beside the estuary. Counts for this section include observations from Mathieson Narrows where there are strong tidal currents and Heathorn Bay. A scattered flock of 67 murrelets were feeding in this shallow sandy bay at the very top of Mathieson Channel.

(H) Sheep Pass (1.3 murrelets/km$^{2,\ 0.5\ km\ offshore}$). The cruise line followed the steep-walled north side of this channel. The south side has a more rolling topography and large shallow areas such as Windy Bay and Griffin Pass. When the south side was surveyed in June, those areas contained large numbers of murrelets.

(I) "small inlets" including Carter and Swanson bays; Green, Khutze, Aaltanhash, and Klekane Inlets; and Goat Harbour (4.1 murrelets/km^2, < 0.5 km offshore). In general, these are shallow and narrower than other channels (about 1 km) with some estuarine areas at their heads. They are very quiet and protected by moderately high hills. Murrelets were the most common species in all of them. A fisheries guardian reported seeing large numbers of murrelets in the lagoon at the head of Green Inlet, in June.

(J) Hiekish Narrows (3.5 murrelets/km$^{2,\ <0.5\ km\ offshore}$). This was the only extended stretch of tidal rapids that we passed through and 34 murrelets were actively fishing in it.

(K) Graham Reach (0.4 murrelets/km$^{2,\ 0.5\ km\ offshore}$). This is a wide channel bounded by steep hills and cliffs. It connects to other channels and offers the wind a "good fetch."

Near the entrance to Green Inlet, we passed a solitary Northern Elephant Seal (Mirounga angustirostris) and three Dall's Porpoises.

(L) Fraser and Ursula reaches (2.2 murrelets/km^2, 0.5 km offshore). These channels are very similar to Graham Reach (K). Murrelets were scattered along this reach in low densities but we saw most of the birds (42 of 58) at the junction with MacKay Reach. Perhaps the currents at such an intersection increase the feeding opportunities.

(M) Bishop Bay (2.4 murrelets/km$^{2,\ 0.3\ km\ offshore}$). This was the northernmost small inlet that we visited. At its head huge schools of smelt or some other small fish were trying to enter the outflow of the hotsprings. They had attracted a number of gulls, loons, and mergansers but the presence of eight boats and their noisy crews may have kept the murrelets closer to the mouth of the bay.

(N) Boxer Reach (0.6 murrelets/km^2, 0.5 km offshore). This was the northern limit reached in the interior channels. We ceased counts as we entered Verney Pass, on our way to Hartley Bay, but continued casual observations to Barnard Harbour (O). We saw only 8 murrelets in this segment and only 3 between Verney Pass and Barnard Harbour. The topography is less extreme than that further east and south but we could see no other characteristic that might account for the absence of murrelets.

(O) Campania Sound from Barnard Harbour to the north end of Beauchemin Channel (3.2 murrelets/km^2, 1 to 5 km offshore). This segment passed through wide channels thickly littered with floating debris. The murrelets occurred in large scattered groups along "tidelines" of this flotsam. The densities contrasted sharply with the small numbers of birds seen in the adjacent segment (P) Surf and Racey inlets (0.6 murrelets/km^2). In other aspects, Surf and Racey appeared to be typical small inlets.

The count in Beauchemin Channel was interrupted by an hour long acrobatic display by 100 or more Pacific white-sided dolphins (Lagenorhynchus obliquidens) and six Dall's porpoises followed by a display of breaching by a Minke Whale (Baleonoptera acutorostrata).

(P) Surf and Racey inlets (0.6 murrelets/km^2, < 0.5 km offshore). These are two shallow and narrow inlets at the north end of Aristazabal Island. Surf Inlet ends at the decaying dam of a sixty-five year old hydro-electric project that may pose a threat to anyone exploring this area. The large impoundment at the head of the inlet provides a constant flow of fresh water. The shores of both inlets were low-lying compared to the small inlets (I)

further inland.

(Q) Caamano Sound (1.3 murrelets/km^2, 2 to 5 km offshore). This is an area of shallow open sea, from Clifford Bay, east of Byers Island, across Caamano Sound, to Gillen Harbour, Jacinto Island in the Dewdney Group. Rhinoceros Auklets, Cassin's Auklets, and Red-throated Loons (Gavia stellata) were abundant. For most of the segment, we were 2 to 5 km offshore.

(R) Principe and Petrel channels (0.3 murrelets/km^2, 0.3 to 0.5 km offshore). This leg started with a spectacular display by 64 or more Bald Eagles, 30 Red-throated Loons, and 30 Pacific Loons fishing at Glide Island. However, few other birds were seen as we progressed north. Between Elbow and Strouts points in Petrel Channel there were strong currents and a clear tideline. Salinity dropped suddenly from 32.0 ppm to 22.0 ppm but there was no concentration of birds associated with it.

(S) Skeena River estuary (3.1 murrelets/km$^{2,\ 0.5\ km\ offshore}$). This was the only concentration area found north of Bishop Bay and Campania Sound. Pairs of murrelets were feeding actively, close to the mouth of the river.

(T) Chatham Sound from Lima Point in Prince Rupert harbour to Lucy Island (> 5 km offshore). No murrelets were seen in this segment but Lucy Island is an important Rhinoceros Auklet colony and as we approached it, we saw a great many of those birds loafing in groups of up to 20.

Murrelet densities

Throughout the survey, large channels (Mathieson Channel, Graham Reach,and Principe Channel) had densities less than 1 murrelet/Km^2. Narrow channels were divided between southern sites such as Hiekish Narrows (J) with high densites and northern sites almost without murrelets. Only one murrelet was seen in Verney Pass, none through the narrow pass south of Hartley Bay, and only 10 in the entire length of Petrel Channel which is not only narrow but includes areas of very strong tidal currents between Elbow and Strouts points.

Bird distribution and physical parameters

Surface salinities (SSS), surface temperatures (SST), channel widths, and channel depths varied greatly among the legs of the cruise (Table 2) and were tested for affects on murrelet distribution. There was only a weak correlation ($r^2 = 0.09$, $n = 20$) between SST and murrelet density (Fig. 3). However, the negative correlation between the density of murrelets and SSS (Fig. 4) was significant ($r^2 = 0.256$, $n = 20$, $p < 0.05$). This was true both when the data were summarized in the 20 segments of the cruise and across the 330 individual 10 minute blocks. A multiple

regression showed that SSS accounted for 26 percent of the variance in murrelet density and SST a further 9 percent. Channel depth and channel width accounted for less than 1 percent of the variance, each. There was no significant correlation between murrelet density and distance offshore but the sample size is small and not randomly distributed.

Channel width and temperature did seem to restrict the ability of murrelets to find suitable habitat. High densities tended to occur in narrow channels. Most legs (7/10) with murrelet densities greater than the median (1.3 birds/Km^2) were narrower than the median width (2.7 Km). Similarly, 8 of the 10 legs with higher than the median density had SST values above the median (11.1° C). In both cases the exceptions included Campania and Milbanke sounds which were broad, shallow channels close to the open sea and in which we observed large numbers of Cassin's Auklets, Rhinoceros Auklets, and other fish-eating birds.

Correlation between murrelets and other birds

The relationship between murrelets and other birds was inconsistent. There were large numbers of murrelets among the Rhinoceros Auklets in Milbanke Sound but few and none off Cape Caution and in Chatham Sound. Conversely, there were no other alcids, except some solitary Pigeon Guillemots (Cepphus columba), in the sheltered inlets and channels. There was a statistically significant correlation ($r^2 = 0.32$, $n = 20$, $p < 0.05$) between the density of murrelets in a leg and the density of Mew Gulls. During a survey of Mussel Inlet in June, we observed many mixed feeding flocks involving these two species.

CONCLUSION AND RECOMMENDATIONS

The cruise of the F/V Pacific Provider was only a single pass through a complex and varied area. The survey technique was simple and easy to apply but the study did not include any tests or replicates. Vessel speed, noise, and appearance to the birds may affect the counts as much as visibility from the boat, observer endurance, weather conditions, or distance to shore. The conversion of the data to birds/km^2 seems to be a simple and useful method of standardizing the information. These data cannot be used to extrapolate a population but provide an indication of relative abundance over a broad geographic area.

There was great variation in the observed densities of murrelets but they were more abundant and occurred in high densities over a much larger area than would be predicted from the site record cards. The significant correlation between densities of murrelets and the densities of Mew Gulls and between the densities of murrelets and SSS implies a link through the food chain. However, SSS and SST may not be sufficient to characterize the waters used by murrelets. It may prove valuable to examine a

profile of the water structure by recording salinities and temperatures through the foraging depth of the murrelets (about 50 m).

There are also other parameters that should be measured. Because much of the surface layer is derived from runoff, there may be important variations in pH. The water from rivers at the heads of inlets, that originate in glaciers and snow fields, may be much less acidic than water seeping from bogs on the low-lying coastal islands. Turbidity may also be important, especially when plankton blooms develop, and could be measured when temperature and salinity are taken.

We still have little information on the breeding biology of Marbled Murrelets and the significance of non-breeding subadults. Most of the birds seen during this cruise occurred in ones and twos but it is not clear whether the large flock on the Goose Group represented adults that would breed later in the season or late-moulting sub-adults that will not breed for a year or two. Nor do we know what portion of the birds occurring in pairs are actually mature. Unfortunately this is a problem that can only be solved by examining large samples of birds for brood patches and we lack a good method for capturing this species.

One surprising feature of the survey was the presence of large numbers of murrelets in an area lacking the classic old-growth forest that has become associated with murrelet nesting. We saw no large trees (see Campbell et al 1990, pg 70). The densest forests were seen along the shores of Kynoch and Mussel inlets but few of the trees exceded 30 or 40 m in height. Even above the estuaries, at the heads of these inlets, the trees were small and lacked mossy growth on their branches. There were many very old stumps of redcedar on the floodplains but there was no active logging in the area except for a small operation on the north side of Sheep Pass. We did not explore any inland areas, however, and murrelets are known to travel 40 km and more inland. Murrelets do find breeding sites in the area and a young with an egg tooth was observed in Mussel Inlet on 28 June 1990 (PartII, this volume). If this area is as productive as the densities in May promise, it could be valuable to determine the nesting habitats of this population.

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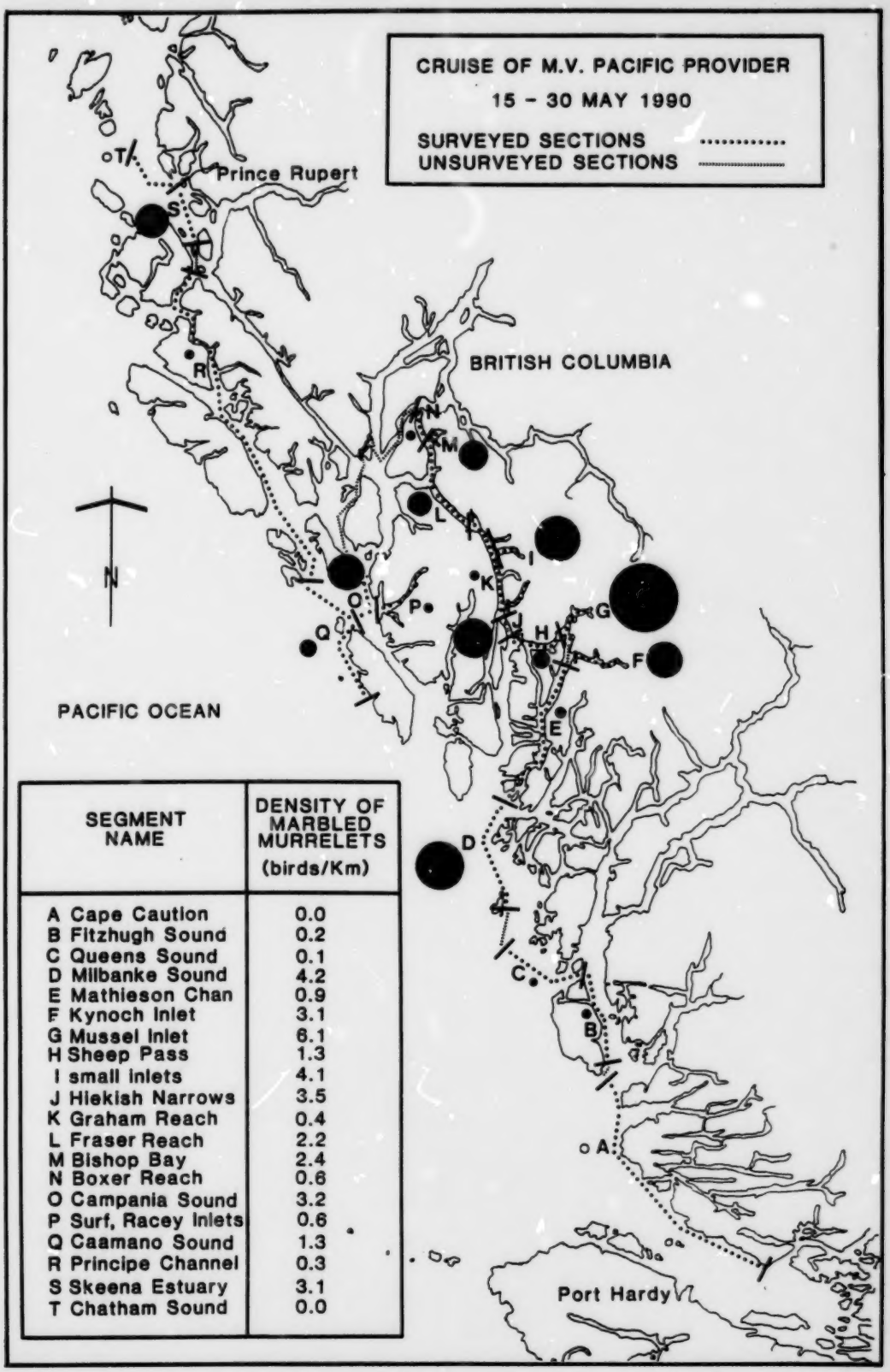

SEGMENT NAME	DENSITY OF MARBLED MURRELETS (birds/Km)
A Cape Caution	0.0
B Fitzhugh Sound	0.2
C Queens Sound	0.1
D Milbanke Sound	4.2
E Mathieson Chan	0.9
F Kynoch Inlet	3.1
G Mussel Inlet	6.1
H Sheep Pass	1.3
I small inlets	4.1
J Hiekish Narrows	3.5
K Graham Reach	0.4
L Fraser Reach	2.2
M Bishop Bay	2.4
N Boxer Reach	0.6
O Campania Sound	3.2
P Surf, Racey Inlets	0.6
Q Caamano Sound	1.3
R Principe Channel	0.3
S Skeena Estuary	3.1
T Chatham Sound	0.0

Figure 1. Densities of Marbled Murrelets along the route of the M.V. Pacific Provider, 15 to 30 May 1990.

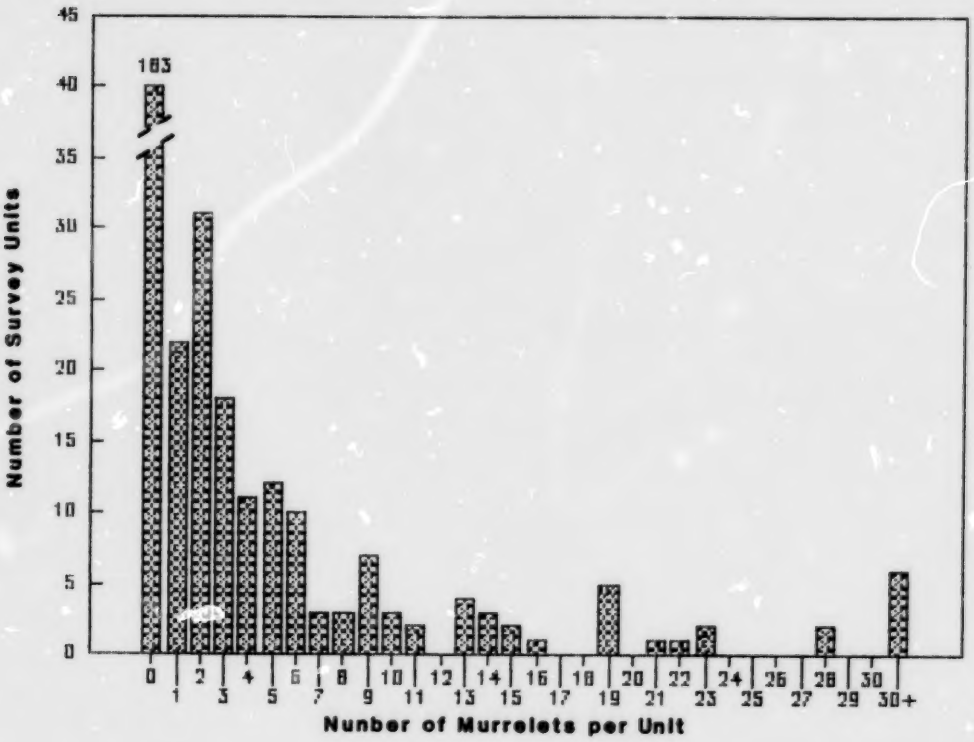

Fig.2. Distribution of murrelets within 10 minute count units.

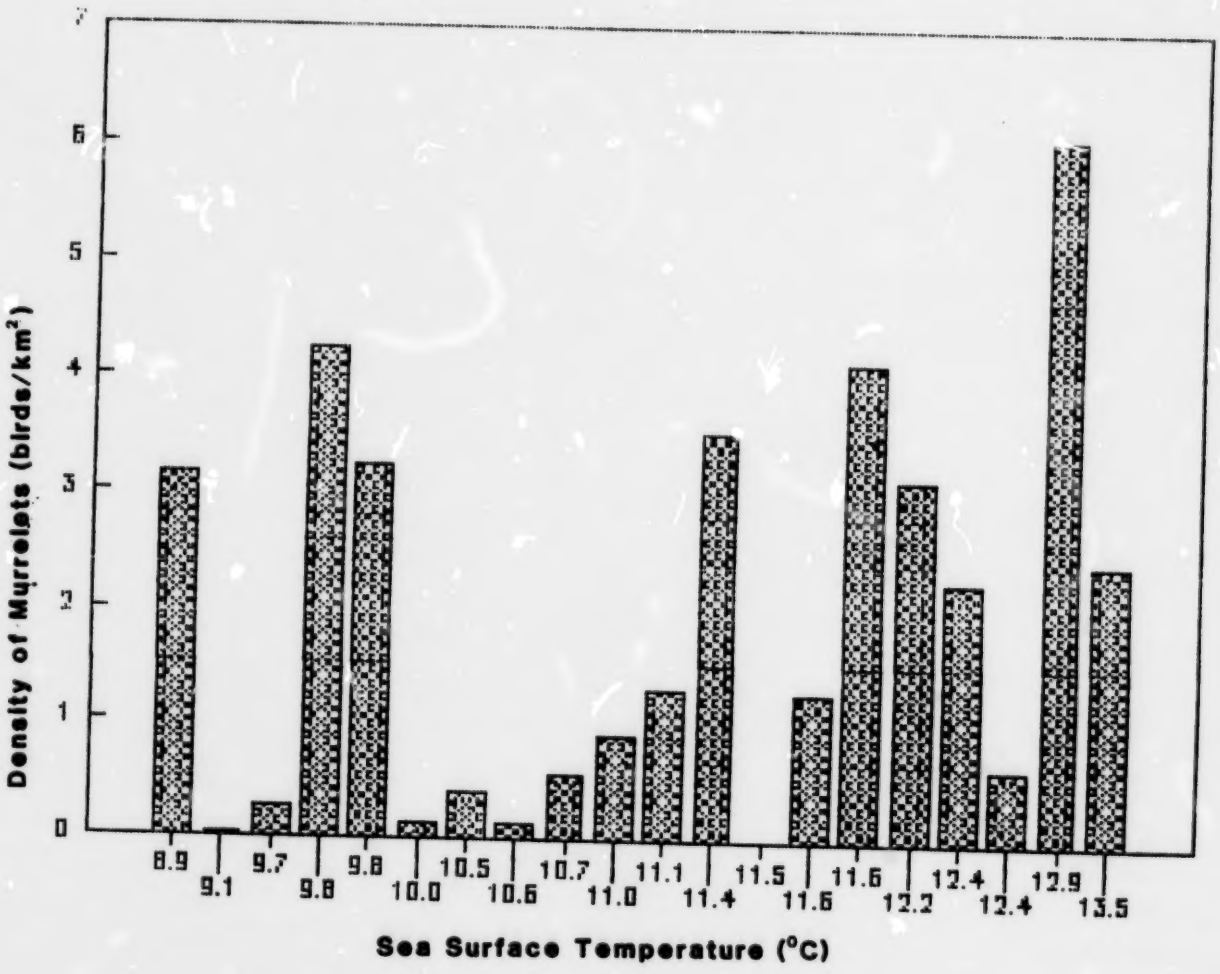

Fig. 3. Densities of Marbled Murrelets at various sea surface temperatures.

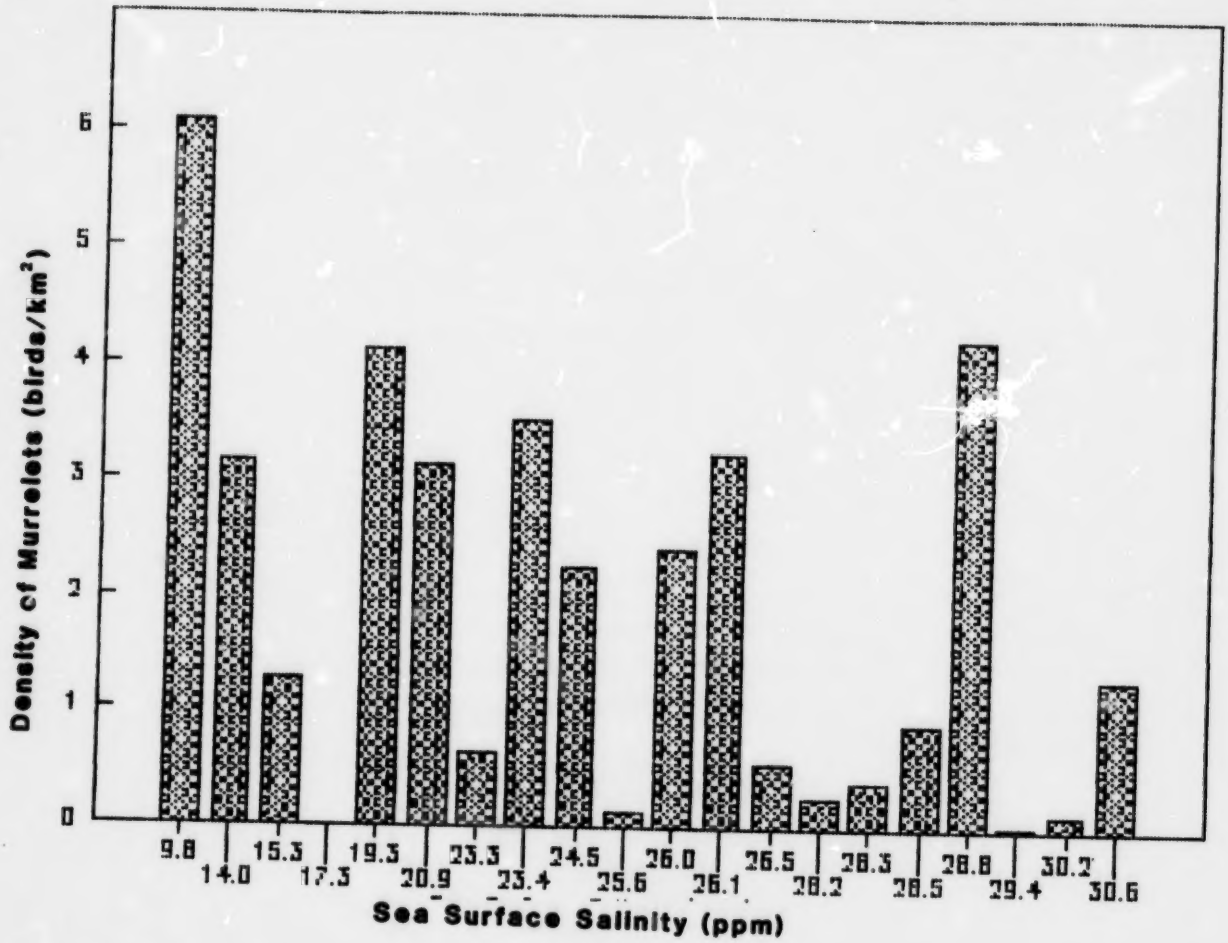

Fig. 4. Densities of Marbled Murrelets at various sea surface salinities.

Table 1. Summary of observations of fish-eating birds during the cruise of the M/V Pacific Provider, May 1990.

	SPECIES OF FISH-EATING BIRDS														
PLACE	MAMU	COLO	PALO	RTLO	RHAU	CAAU	COMU	PIGU	GWGU	MEGU	BOGU	BAEA	WEGR	COME	TOTAL
C CAUTION	2	1	39	0	34	68	123	4	54	0	0	1	0	0	326
FITZHUGH	5	2	41	1	4	0	4	4	17	1	0	4	0	0	83
QUEENS	3	0	41	0	54	146	6	0	39	0	0	2	0	0	291
MILBANKE	149	0	30	2	19	127	8	0	49	0	0	132	0	0	516
MATHIESON	42	2	0	9	0	1	0	1	16	19	35	17	12	0	154
KYNOCH	114	0	0	2	0	0	0	4	0	85	13	1	0	7	226
MUSSEL	126	13	0	1	0	0	0	1	0	53	0	7	0	4	205
SHEEP	20	0	0	5	0	0	0	0	0	19	0	2	0	2	48
small inlets	202	3	0	5	0	0	0	0	0	60	56	19	0	45	390
HIEKISH	58	0	0	0	0	0	0	0	3	26	0	3	0	3	93
GRAHAM	4	0	0	0	0	0	0	0	2	6	0	1	0	1	14
FRASER/URSULA	70	0	0	3	0	0	0	0	0	36	1	3	14	0	127
BISHOP	32	2	0	2	0	0	0	0	0	49	0	0	3	0	88
BOXER	14	1	0	1	0	0	0	3	0	9	0	0	0	0	28
CAMPANIA	96	0	0	2	0	0	0	0	0	30	0	4	0	0	132
SURF	13	1	0	9	0	0	0	0	0	9	0	7	0	9	48
CAAMANO	53	0	6	18	108	20	0	3	28	3	0	2	0	0	241
PRINCIPE/PETREL	21	3	7	10	1	0	0	0	35	24	0	74	3	0	178
SKEENA	56	3	0	0	13	0	0	21	8	5	0	0	9	0	115
CHATHAM	0	2	1	6	18	0	1	1	56	0	0	2	1	0	88
TOTAL	1080	33	165	76	251	362	142	42	307	434	105	281	42	71	3391

Table 2. Summary of physical parameters and bird densities along the route of M/V Pacific Provider, May 1990.

LEG NAME	SEA SURFACE TEMPERATURE (C)	SEA SURFACE SALINITY (ppm)	CHANNEL DEPTH (f)	CHANNEL WIDTH (Km)	MARBLED MURRELETS MAMU	FISH-EATING BIRDS	DENSITY MARBLED MURRELETS (birds/sqKm)
C CAUTION	9.1	29.4	66.9	86.7	2	347	0.0
FITZHUGH	10.6	25.6	159.8	6.3	5	79	0.2
QUEENS	10.0	30.2	79.7	99.0	3	279	0.1
MILBANKE	9.8	28.8	66.7	48.6	149	397	4.2
MATHIESON	11.0	28.5	123.8	2.9	42	138	0.9
KYNOCH	12.2	20.9	135.8	1.0	114	225	3.1
MUSSEL	12.9	9.8	88.8	0.6	126	196	6.1
SHEEP	11.6	15.3	173.1	1.0	20	48	1.3
small inlets	11.6	19.3	55.5	1.0	202	348	4.1
HIEKISH	11.4	23.4	86.0	1.1	58	90	3.5
GRAHAM	10.5	28.3	130.8	1.0	4	13	0.4
FRASER/URSULA	12.4	24.5	208.8	2.4	70	117	2.2
BISHOP	13.5	26.0	174.8	2.0	32	94	2.4
BOXER	12.4	23.3	105.1	2.0	14	29	0.6
CAMPANIA	9.8	26.1	106.5	6.8	96	128	3.2
SURF	10.7	26.5	127.1	1.0	13	46	0.6
CAAMANO	11.1	30.6	84.1	61.0	53	248	1.3
PRINCIPE/PETREL	9.7	28.2	66.2	4.0	21	104	0.3
SKEENA	8.9	14.0	28.5	4.5	56	115	3.1
CHATHAM	11.5	17.3	34.3	6.4	0	86	0.0
AVERAGE/TOTAL	11.0	23.8	105.1	17.0	1080	3127	1.9

II. MARBLED MURRELETS IN MUSSEL INLET, JUNE 1990

keywords:Marbled Murrelet, British Columbia, distribution, marine habitat.

Abstract: A short visit to Mussel Inlet revealed a large number of Marbled Murrelets (Brachyrampus marmoratus) including a young-of-the-year. Murrelets, which were the most abundant bird in the inlet, appeared to be feeding on juvenile Pacific herring (Clupea harrenqus) and Pacific sand lance (Ammodytes hexapterus). Sea surface temperatures and salinities had changed little since a visit 37 days earlier.

Résumé: Une courte visite à l'anse Mussel a indiqué la présence d'un grand nombre d'alques marbrés (Brachyramhus marmoratus), comprenant des jeunes de l'année. L'alque marbré, l'espèce d'oiseau la plus abondante de l'anse, semblait s'alimenter de jeunes harengs du Pacifique (Clupea harrenqus) et de lançons d'Amerique (Ammodytes hexapterus). La température et la salinité de l'eau de surface avaient à peine changées depuis nos dernières mesures 37 jours plus tôt.

INTRODUCTION

Following the cruise of the F/V Pacific Provider (Part I, this volume), we decided that a return visit to Mussel Inlet would provide valuable information about the stability of Marbled Murrelet concentrations and breeding activity in that area. It would also provide an opportunity to evaluate the potential of the area as the site for longer term studies. This report describes surveys on 26, 27, and 28 June 1990 in areas first visited on 19 and 20 May 1990.

STUDY AREA

Mussel Inlet is a steep-walled, deep inlet at the head of Mathiessen Channel (Fig. 1). It has two mouths. One opens through Mathiesson Narrows (52° 51' N, 128° 06' W) into Heathorn Bay and the other opens into Sheep Pass. It also has two heads: Oatswish Bay is a shallow area with poor circulation and few sources of freshwater; Mussel Bay (52° 55' N, 128° 04' W), at the head of the eastern arm of the inlet, has a well developed estuary at the mouth of a small river. Large creeks flow into Poison Cove and David Bay which are shallow embayments of that eastern arm. In the western arm of the inlet, freshwater arrives from waterfalls at the exits of Lizette and McAlpin lakes and there are no shallow embayments.

East of Griffin Pass, the north side of Sheep Pass is typically steep-walled but Pooley Island on the south side is more low-lying and there are large shallow areas (e.g. Windy Bay and Griffin Pass itself).

Parts of this area are in the Fiordlands Recreational Area and there is little evidence of human activity. Hunters and fishermen have constructed two cabins on the north side of the east arm of Mussel Inlet. Paul Harding (pers. comm.), a fisheries officer, has cleared trails for access to the upper estuary. The remnants of large stumps indicate that western redcedars (Thuja plicata) had been cut many years ago but there is no other sign of logging in the area except a small operation on the north side of Sheep Pass.

METHODS

Surveys were conducted from a 4m inflatable boat along a line about 100m from the shore. We recorded all birds seen in survey segments between major landmarks. Attempting to use 10 minute blocks for such a small area was not practical.

Water samples were collected in a 0.5 l bucket from beside the boat. Surface temperature was measured by a thermometer with 1° C gradations and salinities were measured to 0.5 ppm with an American Optical refractometer.

OBSERVATIONS

For most of each survey, the sea was glassy and birds were clearly visible to 500 m. However, at the wide junction of the east and west arms of Mussel Inlet and throughout Sheep Pass, there were rippled areas that required more careful scrutiny.

Marbled Murrelets were the most abundant bird in the study area and the only alcid, except for a few (no more than 10) Pigeon Guillemots (Cepphus columba). Most murrelets occurred singly or in pairs except for short-lived groups of up to 6. These larger groups seemed almost to form by accident as pairs drifted close to each other and we detected no interactions. Sometimes, they seemed to form large groups in response to the noise and disturbance caused by our boat. That was not a behaviour we have seen in Desolation, Clayoquot, or Barkley sounds where small boat traffic is more frequent. We did see one group of 10 actively feeding on the east side of Griffin Pass and smaller groups feeding in David Bay. The only other large flock consisted of 8 birds in a string in the middle of Sheep Pass.

Populations numbers and densities for murrelets were not significantly different from observations made in May. The count through Mussel Inlet and Sheep Pass (27 June) was 20 percent higher than the count for the same area on 19 and 21 May but the June count may have not have been typical. The Mussel Inlet portion of that count was also 20 percent higher than the average of the four days of the June visit. Counts of other fish-eating birds were down 15 percent between May and June.

We saw only one juvenile murrelet (28 June 1990). It was feeding with a loose group of 3 adult birds near the mouth of Poison Cove. It still had an egg tooth.

It rained steadily during most of our visit and we decided that surface salinities and temperatures would be meaningless if collected before there was some opportunity for mixing with subsurface waters. We did collect one set in the east arm of Mussel Inlet, when the weather cleared briefly on the evening of 26 June but were unable to replicate the measurements on other days. Surface salinities were low: 0.0 ppm in the estuary and in Poison Cove, 4.0 to 10.0 ppm along the north shore, and 16.0 ppm in David Bay. Surface temperatures increased slightly from 10.5° C in the estuary to 12.5° C in David Bay. In May temperatures at the same sites had been slightly warmer (11.0° C to 14.0° C) but salinities were the same (Part I, this volume). At this time, temperatures in the Okeover Inlet Study Area were much higher and averaged 16.2° C (range 15° C to 17° C). Salinity was also much higher and averaged 22.3 ppm (range 19.0 ppm to 24.0 ppm) (Part III, this volume).

Murrelets feeding in David Bay and Poison Cove worked the centre of the channel and appeared to be taking sand lance about 10 cm in length. Murrelets feeding in the main body of Mussel Inlet worked deep water near shore. On four occasions, we saw murrelets drive schools of small herring to the surface. They appeared to be coralling the fish against a rock face. During the surveys, eight birds were seen carrying fish. Two appeared to be herring and two appeared to be sand lance. We could only describe the other four as long and silvery. However, they were either small herring or sand lance.

Actively feeding murrelets were often ignored by gulls but we several saw mixed-species feeding flocks that included murrelets and Mew Gulls (Larus canus) or Bonaparte Gulls (L. philadelphia) but not both at the same time. Both gull species attacked boils of fish on the surface by trying to snatch fish while in flight. We did not see the aggressive plunging used by Glaucous-winged Gulls (L. glaucescens) in the same circumstances, nor, did we see large flocks of gulls gathering where murrelets were feeding (Mahon et al. in prep.). Only one or two gulls were involved at any one time. In one case, Mew Gulls joined murrelets that had forced herring to the surface. In three other cases, Bonaparte Gulls joined murrelets attacking sand lance in the shallows of David Bay, Poison Cove, and Griffin Pass. At Griffin Pass, there were roughly equal numbers of murrelets and Bonaparte Gulls (42) but while all of the murrelets were fishing, only four of the gulls joined in. During 15 minutes, none of the gulls were successful.

CONCLUSION

The population of birds seen in May, was not a migrating or ephemeral group of sub-adults but contained a stable component of resident and breeding birds. Unless this population nests in a hitherto undescribed habitat for the species, it is unlikely to nest east of the inlets (but see Simons 1980). There are no large trees along the course of the inlets and the valleys at the inlet heads quickly climb to snow fields (see aerial photo in Campbell et al. 1990 pg. 70). There may be large trees and typical nesting habitat around some of the small lakes on headlands and islands west of the inlets.

The murrelets appear to adopt different feeding strategies in different parts of the coast. In Mussel Inlet, they exploit both herring and sand lance and formed some mixed-species feeding flocks with Mew Gulls and Bonaparte Gulls. This contrasts sharply with the nearly exclusive exploitation of sand lance in the Okeover Inlet Study Area and the frequent formation, there, of mixed-species feeding flocks with Glaucous-winged Gulls (Mahon unpub.). On the west coast of Vancouver Island, the prey include northern anchovy (Engraulis mordax) and murrelets play a minor role in mixed-species feeding flocks (Carter 1984, Sealy and Carter 1984, Carter and Sealy 1987).

The murrelets in Mussel Inlet appeared to react to the presence of the boat. This may be due to the general absence of human activity in the area and should be taken into account for both surveys and behavioural studies because it has a temporary effect on group size and activity.

Although the May and June surveys used very different boats, we feel that the results are comparable. Initially, we were concerned that birds would be more difficult to see from the inflatable boat than from the 15 m fishing boat used in May. However, there was little wind and birds were highly visible on the glassy water, at least as silouettes, to the middle of Mussel Inlet. A larger boat would have provided better coverage of Sheep Pass but no species was abundant,there, except in the shallow bays (Windy Bay and Griffin Pass) in which visibility was very good and a larger boat could not have manouvered.

Mussel Inlet may prove a useful study area for Marbled Murrelets but weather and logistics need to be considered carefully. We found no usable tent sites. Only part of Griffin Pass was explored but the gentler shores of Pooley Island offer several sites for field stations and access to many murrelets.

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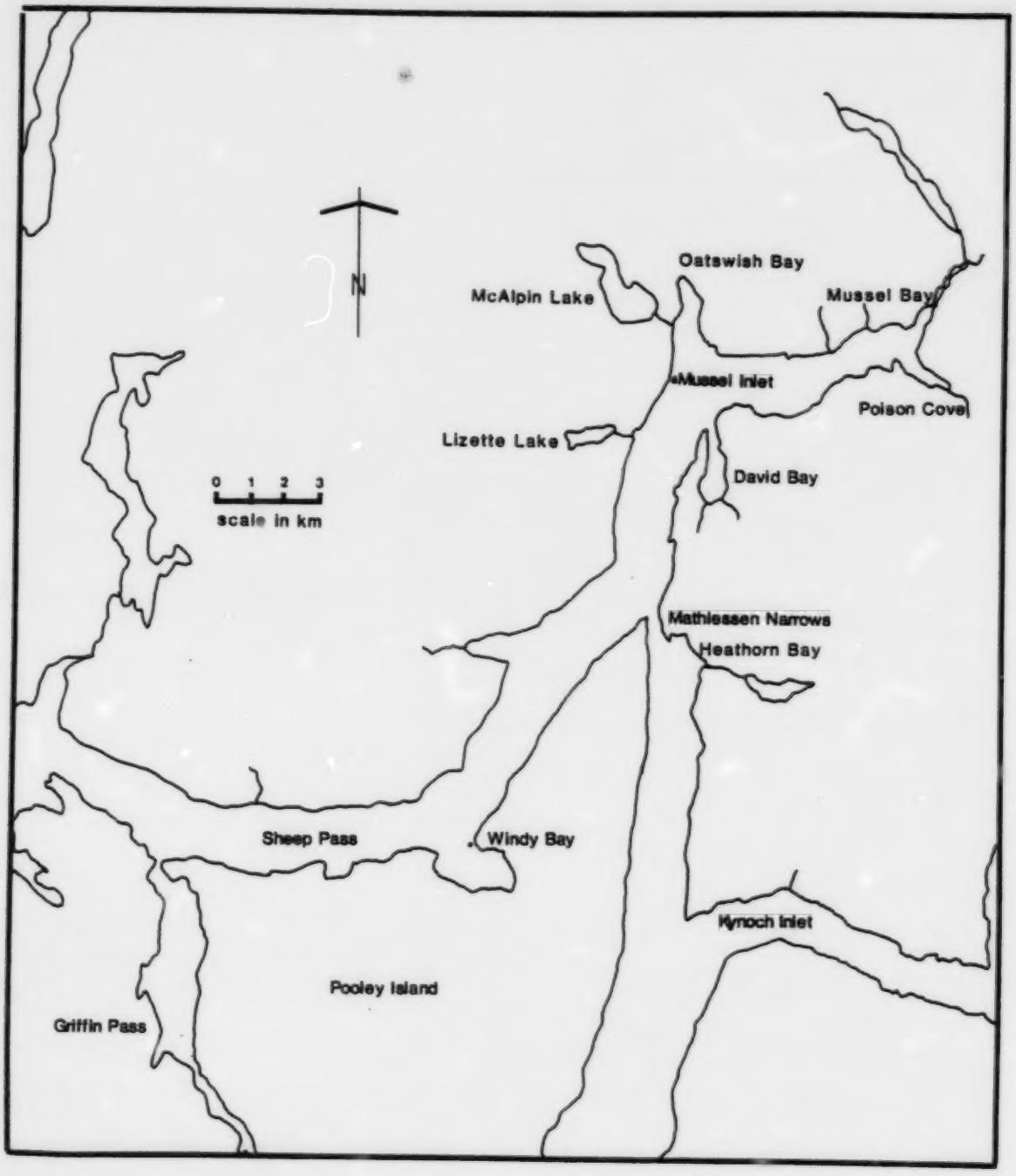

Figure 1. The Mussel Inlet and Sheep Pass area.

TABLE 1. OBSERVATIONS OF MARBLED MURRELETS IN MUSSEL INLET AND SHEEP PASS, 26-28 JUNE 1990.

SURVEY SEGMENT	NUMBERS OF MARBLED MURRELETS JUNE 26	27	28	28	SEGMENT LENGTH (km)	SEGMENT AREA (km2)	MURRELET DENSITY (birds/ km2)	MAY 19	MURRELET DENSITY (birds/ km2
North side Mussel I	10	24	35	40	3.8	2.4	11.4	23	9.7
South side Mussel I	20	8	47	11	5.2	3.3	6.5	12	3.6
David Bay	15	29	15	21	2.1	0.9	21.5	7	7.5
Poison Cove	33	15	34	23	1.0	0.4	73.7	0	0.0
Mussel Bay	4	6	7	7	2.0	1.2	4.8	2	1.6
Oatswish Bay	5	16	6	11	3.3	1.5	6.4	-	-
Thomas Island	3	14	21	5	1.2	0.5	20.4	-	-
West side Mussel I	9	1	4	7	5.6	2.5	2.1	-	-
East side Mussel I	5	8	4	9	5.0	2.3	2.9	5	2.2
Mathiesson Narrows	7	5	8	10	1.1	0.5	15.4	10	20.6
Heathorn Bay	13	10	12	7	1.3	0.6	18.5	76	134.0
Crosson Point	-	9	-	-	3.1	1.4	6.5	3	2.2
Bolin Bay	-	9	-	-	1.3	0.9	9.9	-	-
North Side Sheep P	-	23	-	-	11.0	4.9	4.7	17	3.4
Griffin Pass	-	42	-	-	2.3	1.1	39.9	-	-
South side Sheep P a	-	13	-	-	5.9	2.7	4.9	-	-
Windy Bay	-	33	-	-	2.2	1.6	21.2	-	-
South side Sheep P b	-	32	-	-	7.4	3.3	9.6	-	-
Mussel Inlet Total	124	136	193	151	31.4	16.0	9.4	[173]	15.0
Sheep Pass Total	-	161	-	-	33.1	15.8	10.2	[20]	3.2
Area Total (June 27)	-	297	-	-	64.6	31.9	9.3	[193]	10.3

Table 2. Numbers of Marbled Murrelets and gulls observed in Mussel Inlet, June 1990.

	26		27		28		28	
	MAMU	GULLS	MAMU	GULLS	MAMU	GULLS	MAMU	GULLS
North Mussel Inlet	10	0	24	2	35	1	40	3
Oatswish Bay	5	0	16	1	6	0	11	1
Thomas Island	3	0	14	0	21	0	5	0
West Mussel Inlet	9	1	1	0	4	0	7	0
Mathiesson Narrows	7	1	5	0	8	2	10	1
Heathorn Bay	13	2	10	0	12	1	7	1
East Mussel Inlet	5	0	8	3	4	3	9	4
David Bay	15	0	29	4	15	0	21	0
South Mussel Inlet	20	2	8	3	47	4	11	4
Poison Cove	33	4	15	16	34	1	23	4
Mussel Bay	4	11	6	23	7	0	7	17
Crosson Point	-	-	9	0	-	-	-	-
Bolin Bay	-	-	9	3	-	-	-	-
North Sheep Pass	-	-	23	1	-	-	-	-
Griffin Pass	-	-	42	42	-	-	-	-
South Sheep Pass a	-	-	13	24	-	-	-	-
Windy Bay	-	-	33	2	-	-	-	-
South Sheep Pass b	-	-	32	0	-	-	-	-
					-	-	-	-
MUSSEL INLET TOTAL	124	21	136	52	193	12	151	35
SHEEP PASS TOTAL	-	-	161	72	-	-	-	-

APPENDIX I. OBSERVATIONS OF MARINE BIRDS IN MUSSEL INLET AND SHEEP PASS, 26-28 JUNE 1990.

26 JUNE 1990
1254-1429 hrs

SURVEY SEGMENT	COLO	MEGU	BOGU	PIGU	SUSC	HADU	BAEA
North Mussel Inlet		3	8				2
South Mussel Inlet	1	2					2
David Bay	3						
Poison Cove		2	2				1
Mussel Bay							
Oatswish Bay				1			2
Thomas Island		1					1
West Mussel Inlet							
East Mussel Inlet							5
Mathiesson Narrows		1					
Heathorn Bay		2					
MUSSEL INLET TOTAL	4	11	10	1	0	0	13

APPEN. I (cont'd). OBSERVATIONS OF MARINE BIRDS IN MUSSEL INLET AND SHEEP PASS, 26-28 JUNE 1990.

26 JUNE 1990
1923-2010 hrs

SURVEY SEGMENT	COLO	MEGU	BOGU	PIGU	SUSC	HADU	BAEA
North Mussel Inlet							
South Mussel Inlet		4					
David Bay		3					
Poison Cove	2	2				2	
Mussel Bay							
Short survey total	2	9				2	

APPEN. I (cont'd). OBSERVATIONS OF MARINE BIRDS IN MUSSEL INLET AND SHEEP PASS, 26-28 JUNE 1990.

27 JUNE 1990
1251-1614 hrs

SURVEY SEGMENT	COLO	MEGU	BOGU	PIGU	SUSC	COME	BAEA
North Mussel Inlet		2					
South Mussel Inlet		3					3
David Bay		2	2		1		
Poison Cove	4		16				1
Mussel Bay			23				1
Oatswish Bay		1					
Thomas Island							4
West Mussel Inlet							
East Mussel Inlet	4	3					1
Mathlesson Narrows							2
Heathorn Bay							
Crosson Point							
Bolin Bay			3	1		1	
North Sheep Pass			1		4		2
Griffin Pass			42	1			
South Sheep Pass a		24				4	3
Windy Bay		2		2	11		1
South Sheep Pass b							3
MUSSEL INLET TOTAL	8	11	41	0	1	0	12
SHEEP PASS TOTAL	0	26	46	4	15	5	9

APPEN. I (cont'd). OBSERVATIONS OF MARINE BIRDS IN MUSSEL INLET AND SHEEP PASS, 26-28 JUNE 1990.

27 JUNE 1990
2037-2121 hrs

SURVEY SEGMENT	COLO	MEGU	BOGU	PIGU	SUSC	COME	BAEA
North Mussel Inlet		1	10				2
South Mussel Inlet		6					1
David Bay							
Poison Cove	2	1					2
Mussel Bay							
Short survey total	2	8	10	0	0	0	5

APPEN. I (cont'd). OBSERVATIONS OF MARINE BIRDS IN MUSSEL INLET AND SHEEP PASS, 26-28 JUNE 1990.

28 JUNE 1990
1254-1429 hrs

SURVEY SEGMENT	COLO	MEGU	BOGU	PIGU	SUSC	COME	BAEA
North Mussel Inlet		1					
South Mussel Inlet	3	4				1	2
David Bay							1
Poison Cove		1					
Mussel Bay							
Oatswish Bay							
Thomas Island							1
West Mussel Inlet							
East Mussel Inlet	5	3					2
Mathiesson Narrows		2					1
Heathorn Bay		1					
MUSSEL INLET TOTAL	8	12	0	0	0	1	7

APPEN. I (cont'd). OBSERVATIONS OF MARINE BIRDS IN MUSSEL INLET AND SHEEP PASS, 26-28 JUNE 1990.

28 JUNE 1990
1434-1603 hrs

SURVEY SEGMENT	COLO	MEGU	BOGU	PIGU	SUSC	HADU	BAEA
North Mussel Inlet		3					1
South Mussel Inlet		4				2	
David Bay	2						
Poison Cove			4	1			
Mussel Bay		1	16				
Oatswish Bay	2	1					1
Thomas Island							1
West Mussel Inlet							
East Mussel Inlet	*2	4					1
Mathiesson Narrows		1					1
Heathorn Bay	2	1					
MUSSEL INLET TOTAL	6	15	20	1	0	2	5

*RTLO

III. BREEDING SEASON SURVEYS OF MARBLED MURRELETS IN A COASTAL INLET

keywords: Marbled Murrelet, population density, marine habitat.

Abstract: Replicated surveys in a cluster of small inlets indicate that populations estimates remained stable through June but became eratic in July. Increases in sea surface temperatures correlate to changes in distribution of the murrelets. Possibly, the temperatures force a change in the distribution of the murrelet's prey - sand lance. Young-of-the-year were scarce until late July and did not become abundant until August. Implications for surveys and conservation efforts are discussed.

Résumé: Une combinaison de recensements conduits dans un groupe de petites anses a indiqué que les populations d'alques marbré (Brachyramphus marmoratus) demeurent stables en juin mais varient grandement en juillet. La distribution des alques est correlée avec la température des eaux de surface. Les températures jouent possiblement un rôle dans la distribution du lançon d'Amérique, dont les alques s'alimentent. Les alques juveniles étaient rares avant la fin juillet et ne devinrent abondant qu'en août. Les implications pour les efforts d'échantillonage et de conservations sont discutés.

INTRODUCTION

Marbled Murrelets (Brachyramphus marmoratus) are small, piscivorous alcids that spend most of their lives on the water where they feed. In British Columbia, they are frequently encountered in most coastal waters but their relationship with the marine habitat is poorly understood (Campbell et al. 1990). Brown (1980) showed the importance of considering seabirds as marine organisms by demonstrating that basic characteristics of marine habitats had significant effects on the distribution of seabirds in Chilean fiords.

Marbled Murrelets were declared a threatened species in 1990 by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). In part this was due to the murrelet's apparent dependence on old-growth forests for nest sites but oil-spills and losses to fishing nets were also identified as important problems. We designed this pilot study to improve our understanding of the murrelets marine activities by examining the population of murrelets in a group of small coastal inlets. We relate fluctuations in their abundance to seasonal changes in the salinity and temperature of the water.

STUDY AREA

The study area included Okeover (midpoint 50° 00' N, 124° 43' W), Theodosia, Lancelot, and Malaspina inlets and the southwestern section of Desolation Sound (Fig. 1). A small portion (about 5%) of the 40 km^2 in the study is protected as a marine park but otherwise the shoreline is extensively developed for summer homes, recreational boating, and mariculture. Facilities for dumping and booming logs have been constructed in both Okeover and Theodosia inlets. Several tidal flats are either under oyster-lease or subject to intensive commercial harvest of clams. Tourist and recreational activity is concentrated in July and August but industrial and resource extraction activities occur throughout the year.

The five inlets are very diverse. Theodosia is the most shallow and narrow often being less than 10 m deep with a well developed estuary and tidal flat at the mouth of the Theodosia River. Near the inlet's mouth, there are strong tidal currents where it narrows to only 100 m. Lancelot and Okeover are small deep (>50 m) fiords. There are no strong tidal currents and only small temporary creeks contribute fresh water. Malaspina Inlet is a narrow and shallow channel connecting Lancelot and Theodosia inlets and several shallow bays to the mouth of Desolation Sound. The channel is constricted by many reefs and islands that contribute to very strong tidal currents. Desolation Sound is a widening at the mouth of Toba Inlet. It is generally deeper and less sheltered than other portions of the study area. There are no sources of fresh water except a small creek entering Tenedos Bay (Fig. 1).

METHODS

Between 6 June and 8 August 1990, we counted all birds from a 5 m open boat within predetermined segments of the inlets (Fig. 1), one observer on each side, scanning a 200 m-wide transect. The route was run at full speed (about 20 km/h) so that the entire 72 km could be completed within three hours. Surveys began before 1000 hrs in the mornings or after 1900 hrs in the evenings. Carter (1984) found that counts of murrelets were most stable during the same survey periods.

For large flocks and for areas wider than 400 m, we stopped the boat and conducted a stationary count. This action was usually necessary in the wide junction of Okeover and Lancelot inlets where large numbers of murrelets and gulls congregated. The route covered 35.5 km^2 of the 40 km^2 in the study area. The route did not include the central portion of Desolation Sound (Fig. 1) which had contained only small numbers of murrelets in previous surveys (G. Kaiser unpub. data).

Because Malaspina Channel often has strong tidal currents through most of its length, the east and west segments were run as close together as possible. This reduced the probability of duplicating counts and ensured similar conditions during each survey segment. Theodosia Inlet, which also had some strong currents, was surveyed within 15 minutes of the completion of Malaspina Channel so that conditions would be similar at both sites.

We collected water samples in a 0.5 L bucket from the surface beside the boat and measured salinity (SSS) to 0.5 ppm with an American Optical refractometer. For surface temperatures (SST) we used a thermometer with 1° C gradations. The sampling sites were usually near the start of each survey segment.

We also counted birds from 11 viewpoints between Saltery Bay, south of Powell River, to Dinner Rock, near Lund. These counts occurred at several different times of the day according to the demands of the boat survey schedule. At the viewpoints, we tallied all birds on the water within 500 m of shore or flying by. We were unable to collect water samples from those sites. The sites included four sandy beaches (Saltery Bay boat launch, McNair Road, Westview Lookout, Gibson's Beach), four protected bays (Lang Bay pier, Brew Bay, Myrtle Beach, Scuttle Bay), and two stretches of open coast (Emmond's Beach, Dinner Rock campsite) (Fig. 2).

RESULTS

Murrelet distribution

During the first survey, on the morning of 6 June 1990, we found murrelets scattered throughout the study area with concentrations in North Desolation Sound, West Lancelot Inlet and the junction of Lancelot, Okeover, and Malaspina inlets. Murrelets remained similarly distributed in all surveys until mid-July when the population of the study area declined significantly (Fig. 2). By the end of July, only Malaspina Channel and its southern entrance consistently contained large numbers of birds. In the two surveys on 8 August, most inner inlets had few murrelets but numbers in Desolation Sound had increased sharply (Fig. 3). On those last surveys, most birds occurred in flocks instead of singly or in pairs and from 25 to 30 percent were young-of-the-year.

This study concluded on 8 August, as the incubation period ended (Campbell et al. 1990). Few murrelets use the inlets in August or September but autumn counts can approach summer numbers (302 murrelets on 3 October 1982, G. Kaiser unpub.). Recently, flocks of murrelets were seen in nearby Bute Inlet during October (R. Burns and L. Prestash pers. comm.).

Population estimates

Populations in the study area varied around a mean of 370 murrelets (S.D. = 158.6, n = 27) (Fig. 3). Before 5 July, the counts were stable at 390 (S.D. = 75.2, n = 9) but on 5 July, we saw 798 birds and counts for the rest of the month fluctuated from highs of 677 and 554 to a low of 107. The mean for July was 359 (S.D. = 192.0, n = 16) with more low counts occurring near the end of the month. Through June and early July, the greatest variation occurred in inner inlets, particularly Okeover Inlet (Fig. 4). By the end of July those sections of the study area were largely abandoned.

Two counts were made on 8 August. In the morning we saw only 86 murrelets and in the evening 101. Of those, 24 and 32, respectively, were young-of-the-year. These were the highest counts and highest percentages of young seen on surveys during the summer.

The marine environment

Physical and biological changes occurred in the inlets which coincided with changes in murrelet distribution. Early in June, the water was clear and along the survey route we saw schools of Pacific sand lance (*Ammodytes hexapterus*) that contained many thousand fish. Surface salinity (SSS) was depressed by heavy rainfall (9 and 10 June) and runoff from creeks was heavy. Water in Theodosia Inlet was particularly stained brown and the SSS value

at the narrows was only 4 ppm. Sea surface temperatures (SST) were low (overall average = 16.2° C) and reached 17° C only in shallow areas with poor circulation (e.g. the end of Lancelot Inlet).

By early July, the water was more cloudy and schools of fish were rare at the surface. Murrelets began concentrating in areas that had strong tidal currents. In mid-July, there was a distinct bloom of algae and jellyfishes were abundant. Murrelets were noticably concentrated in areas with strong currents. SSS remained stable through July even though the creeks dried up. Surface water was not coloured, even in Theodosia Inlet. Melting snow fields and glaciers at the head of Toba Inlet lowered SSS in Desolation Sound. SST values increased slightly in early July (overall mean 18.5° C) and exceeded 20° C at most locations by the end of July. The exceptions were the areas with strong tidal currents in Malaspina and Theodosia inlets where SST remained near June values. In Theodosia Inlet, low SST values may have been produced by the Theodosia River which continued to flow throughout the study period.

By August 8, algae formed scummy patches on the surface and only small numbers of murrelets still used Lancelot, Theodosia, or Okeover inlet (27 in the morning and 22 in the evening). Some birds remained in the narrows of Malaspina Inlet but the largest numbers occurred in Desolation Sound.

Those changes are reflected in a significant negative correlation between SST and murrelet density for the period of the surveys ($r^2 = 0.185$, $n = 15$, $p < 0.05$). The small r^2 value indicates that many other factors also played important roles. The correlation between SSS and murrelet density was not significant ($r^2 = 0.155$, $n = 15$, $p > 0.05$).

Interactions with prey species

Physical changes in the inlets may have influenced the distribution of murrelets through the food chain. Between 6 and 10 June, we saw several large schools of sand lance and many small schools in shallow areas. These fish appeared uniform in size (<100 mm long) and were associated with small groups of murrelets. During a dive, Mahon estimated the volume of one large school to be 3 m^3 and consist of 75 percent sand lance and 25 percent rockfish. Other large schools, containing only sand lance, were seen from the boat, within 100 m of the diver and at the mouth of Theodosia Inlet and the Okeover Inlet government wharf on the same day.

Although, we often observed murrelets within 100 m of large schools of sand lance, the birds did not sit directly over them. On 10 June, we were able to watch a murrelet repeatedly attack and control a small ball of sand lance beneath the Petrocan oil-barge facility at the Lang Bay Pier. The bird would dive at one side of the school, pass under or through it, and surface on the other

side. This process was repeated 10 or 12 times while we watched and the fish seemed unable to leave the area. We never saw the bird catch fish but it may have swallowed some underwater.

During the first evening survey (11 June) eight birds were seen carrying single fish which appeared to be sand lance. For the rest of the study period, sand lance accounted for about 90 percent of the identified prey. On 11 June, we noticed two large mixed feeding flocks. In East Lancelot, 14 and 29 Glaucous-winged Gulls had joined 29 and 13 murrelets, respectively. This type of activity proved to be frequent and generated a separate study (Mahon unpub.). During most surveys, gulls on the water were a reliable indicator of feeding murrelets.

Young-of-the-year

We saw the first young-of-the-year on 14 June 1990 outside the study area, at Mitlenatch Island. This record was 12 days earlier than previous reports for British Columbia (Campbell et al. 1990). The bird was adult size but still retained the egg-tooth and had tufts of whitish down on its upper flanks. It was not until 22 days later that we saw the next one, in Malaspina Inlet, but, no surveys were conducted in the Okeover Area between 20 June and 1 July. Between 6 and 26 July we saw an average of less than 2 young per survey and never more than 6 on any one count. On 28 July, we saw 12 in Malaspina Inlet and Desolation Sound and one in Theodosia Inlet. In July, young were often seen alone or in the company of one or two adults. Several times, we watched a juvenile join and then leave a pair of adults without any overt interaction on either part. On 8 August, many young occurred in flocks of five and seven together as well as in larger groups with some adults.

There was much variation in the apparent sizes of young. Some appeared to be adult size but others looked 25 percent smaller. If such observations reflect real differences in size, the young may vary in their degree of development when they leave the nest. We saw no birds that might have been in unusually early or late winter plumage.

All 24 young seen on the morning survey of 8 August were in Malaspina Inlet or Desolation Sound. On that evening, 28 of 32 were in those same areas, 3 of the remainder were in Okeover and Lancelot inlets near the junction with Malaspina Inlet, and 1 was in Theodosia Inlet. Adult birds seen on that day had a similar distribution (Fig. 3).

Breeding and non-breeding components of the population

One objective of this project was the development of criteria for distinguishing non-breeding birds within the resident population by criteria useful to survey crews. We did observe some variations in appearance (and behaviour, Mahon unpub.) of the population during the surveys. On the first survey, no birds showed any winter plumage but about 1/3 appeared to be a lighter brown than the others. They also had a distinct pale patch on the upper flanks; an area that is white in winter plumage. We were unable to tally those birds and relate their activities to differences in flock size because the individual variation in plumage was too subjective. Birds appeared darker when backlit by the sun or seen in poorer light near sunset. Light and dark birds were seen throughout the survey period but we can suggest no significance to this variation. We did not observe any other variations in appearance of the murrelets.

Ground counts

Population fluctuations from ground counts were similar to patterns observed in boat surveys but variance was much higher. On 6 July, we counted 378 murrelets, 181 in Scuttle Bay, alone. Prior to that time the mean had been only 39.6 (S.D. = 23.1) and afterwards the mean fell to 29.6 (S.D. = 22.8). No young were seen from any of the viewpoints along the Malaspina Peninsula but somew were seen during boat trips to Mitlenatch Island in the Strait of Georgia.

Ground counts were influenced by winds as all sites were open to the prevailing westerlies. In bright sunlight, even light breezes interferred with observations and during stronger winds, murrelets appeared to move to more sheltered sites.

Human activity may also have been important. The viewpoints lay along Highway 101 or at the ends of sideroads and all had some form of recreational or industrial activity.

DISCUSSION

Population estimates

The dense concentration of murrelets in the Okeover Study Area is difficult to interpret. Part of the population appears to consist of resident birds (about 350) that is joined in early July by an equal number of birds of unknown origin and unknown breeding status. The sudden arrival of such a large group suggests a migration of non-breeding subadults. Comparable increases in terrestrial activity by murrelets in July have been attributed to sub-adults prospecting for nest sites (e.g. Rodway et al. 1991, Paton and Ralph 1988).

Designs for larger scale murrelet surveys must take these

observations into consideration. Estimates of resident or breeding populations should only be based on surveys in May and June. Very early counts in May could include migrants (PART I, this volume) while counts in July will be influenced by the influx of new birds. After the July surge in numbers, increased variance also impedes effective estimates of resident populations.

Marine Environment

The observations suggest an important link between murrelet distribution and marine habitat conditions (SST and SSS). The causal link may be through the food chain. Prey were abundant near the surface at low temperatures but were not seen when SST reached 20° C. This is the temperature at which sand lance become inactive in laboratory experiments (Field 1980, Girsa and Danilov 1976, Winslade 1974). They are most active between 5° C and 15° C. To find their preferred temperatures. sand lance may leave the shallow inlets, move to cooler, deeper water, or burrow into the bottom (Field 1988). All three actions could make them unavailable to murrelets except where turbulence carries cold water into their diving range. Even in late July and early August, the tidal rapids and whirlpools of Malaspina Narrows attracted feeding-flocks of murrelets.

Our understanding of relationships between the physical environment and murrelet prey could be refined by more detailed measurements. SST may not be an accurate index of the factors affecting prey distribution but it is not difficult to construct a temperature and salinity profile from samples collected at various depths. Concurrently, the characteristic signal of sand lance on a depth sounder could be used to identify their depth (and temperature) preferences.

The distribution of 103 young-of-the-year also implies a link to variables in the marine environment. All but 13 occurred in Desolation Sound or Malaspina Inlet where there were large numbers of adults throughout the later parts of the survey period. Before 28 July, 24 percent of the young (n = 34) occurred in the inner inlets along with moderate numbers of adult birds.

In mid-July, murrelets begin to disperse from the more sheltered inlets, probably because prey become less available. The moult into winter plumage occurs in August and September and murrelets may need to seek richer food sources. The post-breeding moult is another phase of the murrelet's life history which requires study.

CONCLUSION

The population of Marbled Murrelets in the Okeover Study Area is the densest reported to date. It is also the single largest concentration yet discovered on the British Columbia coast. This makes the acceleration of piecemeal development in the inlets a serious conservation issue. This area has already been extensively logged and we found no stands of old-growth forest typical of murrelet nest sites close to our study area. Since 1982, oyster leases and clam digging have expanded onto most of the tidal flats, dozens of permanent and summer residences have been built along the shore, and two new marinas have been established. We have no information about the consequences of this sort of development on murrelet populations.

The absence of nearby nesting sites offers an explanation for the small number of young-of-the-year observed in the inner inlets. However, hundreds of adult murrelets congregate, there, to exploit rich stocks of sand lance. Those stocks will be adversely affected by any activity that increases the pollution of the inlets and speeds the onset of the summer algal bloom.

This population's accessibility and proximity to Powell River make it ideal for further research into its breeding biology and response to environmental conditions. Actual nesting sites may be distant from the Okeover Area but there are numerous marinas and airports, nearby, to support far-ranging telemetry projects.

Future studies should include additional physical measurements including: temperatures and salinities at various depths, turbidity, acidity, and total dissolved oxygen. Behaviour and migration studies need to begin in January with surveys of the flocks off the Sechelt Peninsula, 60 km south. They may follow the dense blooms of euphausiids (Mackas and Fulton 1989) or drifting masses of larval sand lance that occur in that area. If birds wintering in the Strait of Georgia are the source of the breeders in the Okeover Study Area, they offer a valuable opportunity to study the whole annual cycle and marine biology of this species.

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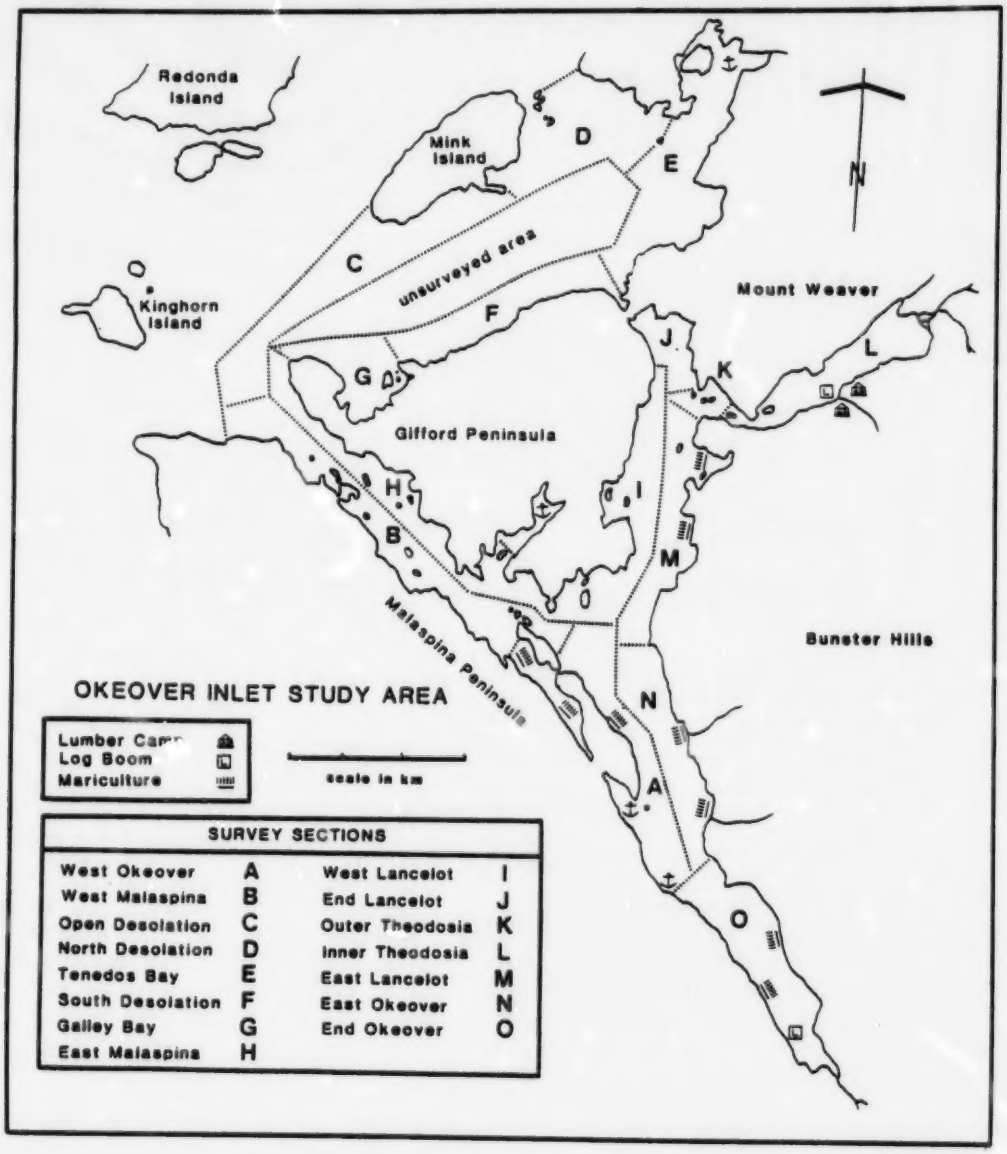

Figure 1. Survey segments within the Okeover Inlet Study Area, 1990.

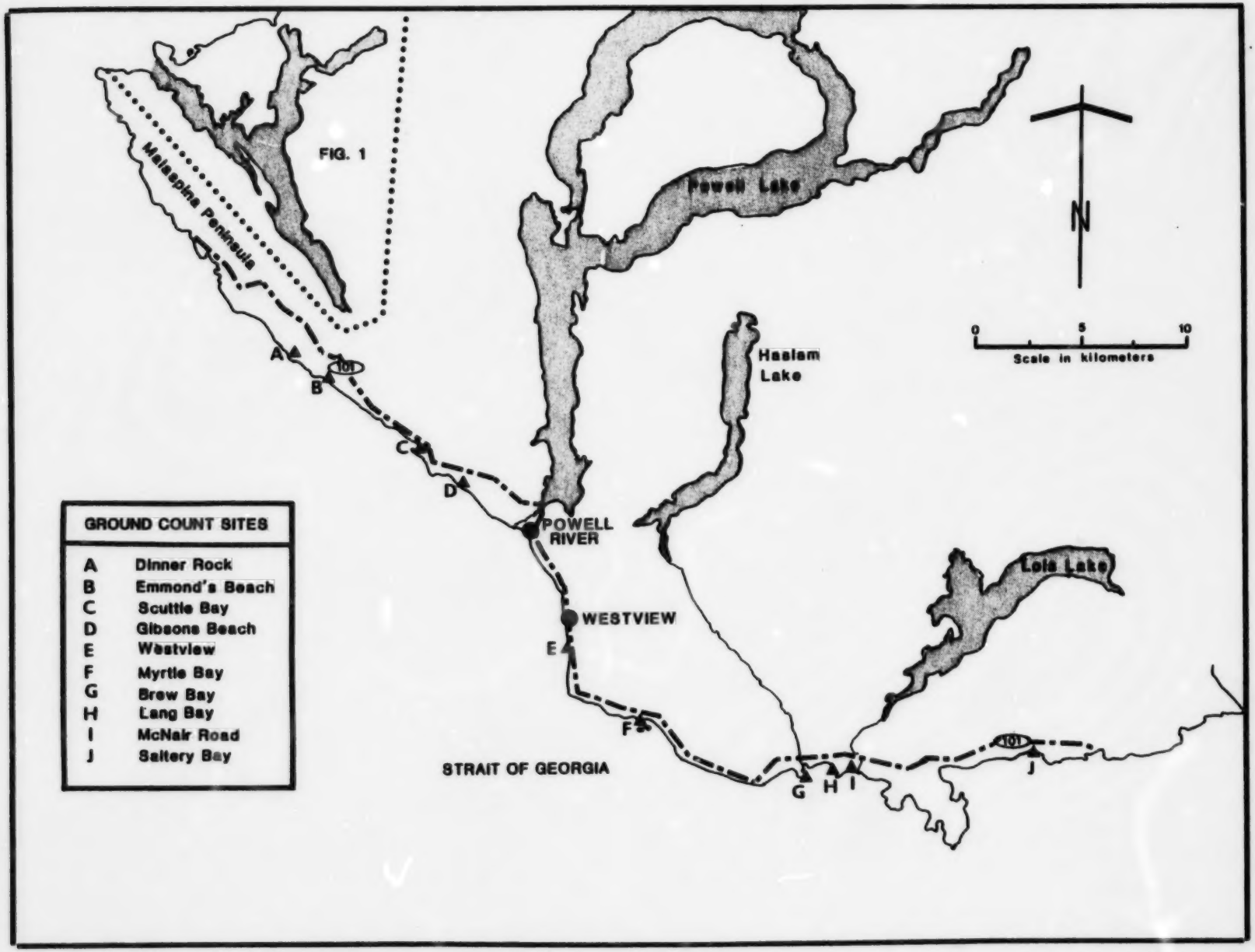

Figure 2. Viewpoints for ground counts of Marbled Murrelets, south of the Okeover Inlet Study Area.

Figure 3

Distribution of Marbled Murrelets in the Okeover Inlet Study Area, 9 June - 8 Aug

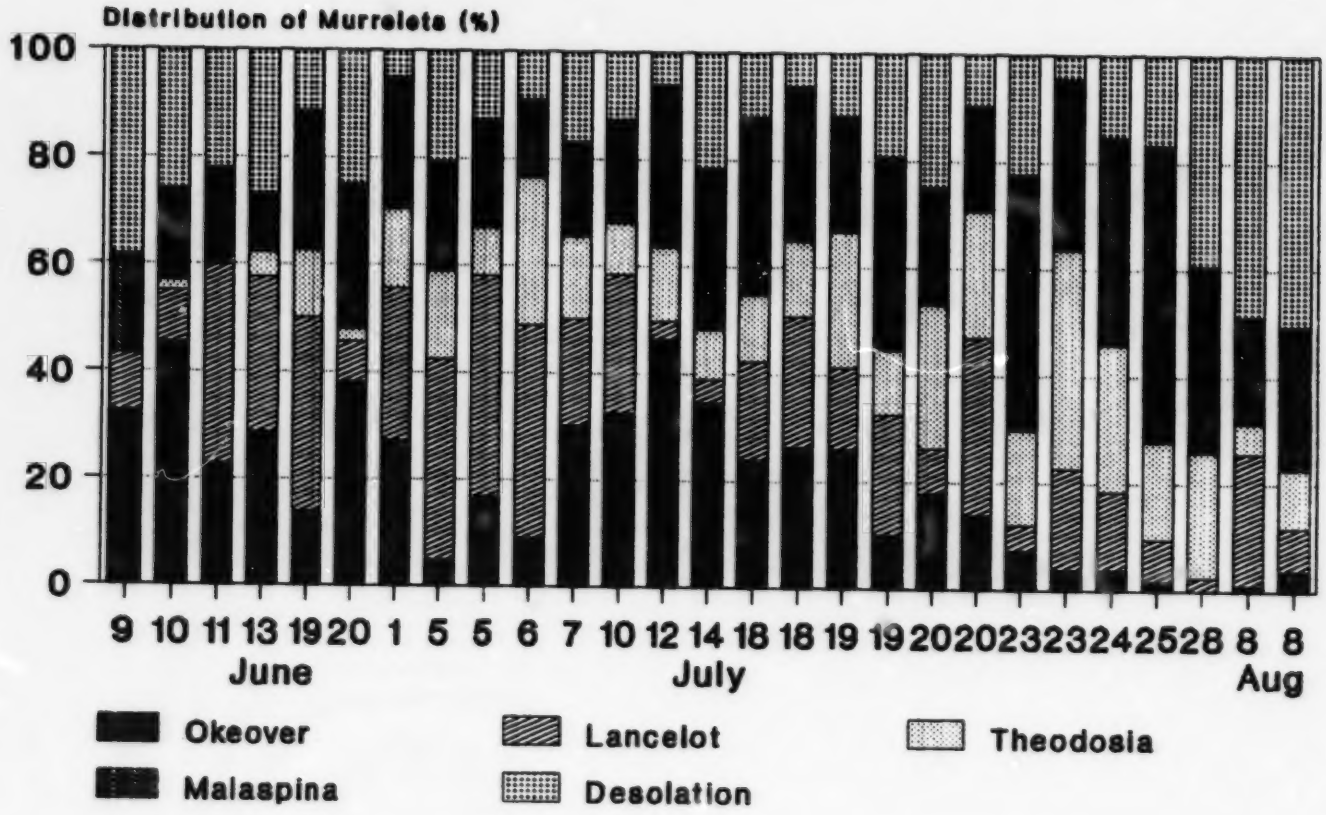

Figure 4

Counts of Marbled Murrelets in the Okeover Inlet Study Area, 9 June - 8 Aug

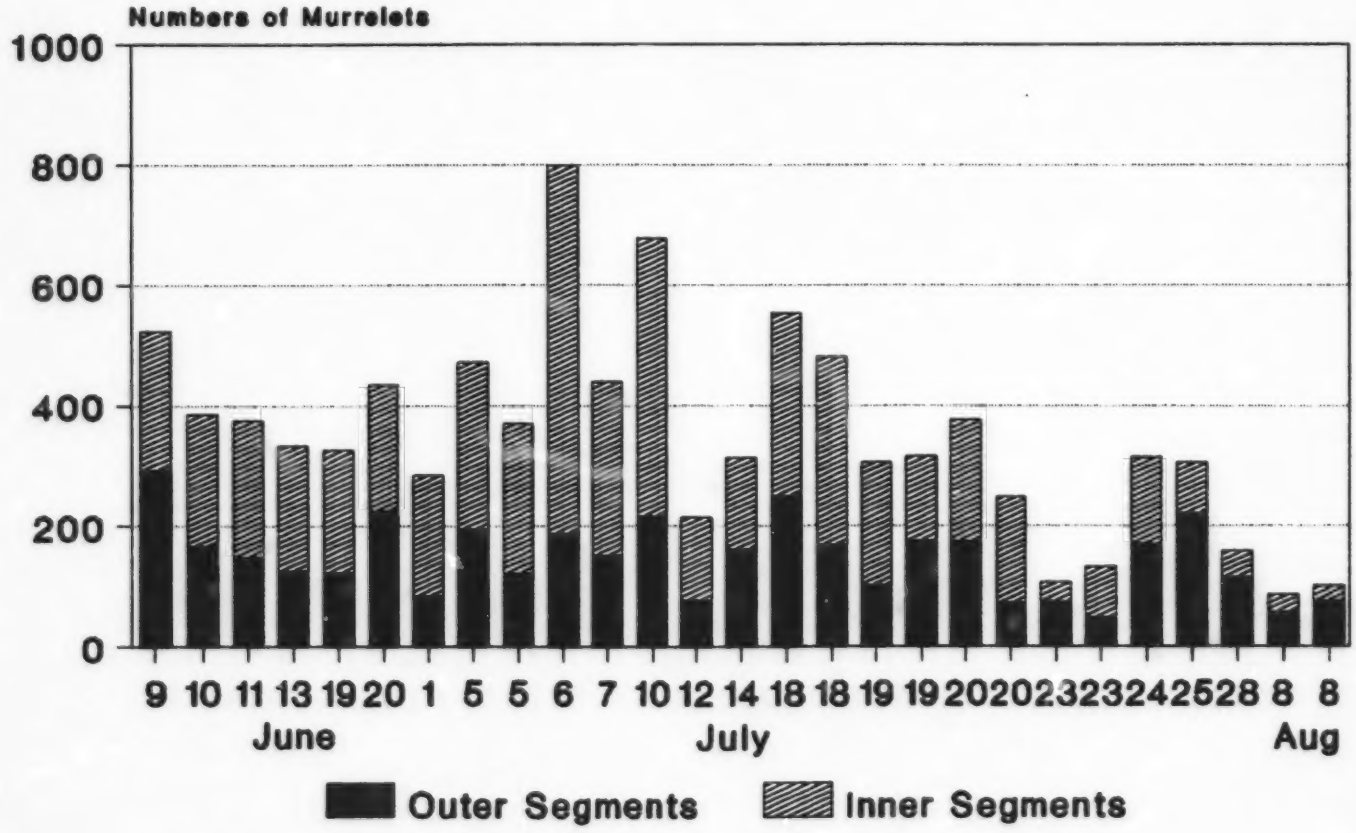

TABLE 1. Observations of Marbled Murrelets during boat surveys of the Okeover Inlet Study Area.

BLOCK	SEGMENT LENGTH (km)	SEGMENT AREA (sq km)	DATE AND TIME OF SURVEY 09 Jun am	10 Jun am	11 Jun am	13 Jun pm	19 Jun pm	20 Jun am	01 Jul am	05 Jul am	05 Jul pm
OKEOVER WEST	5.1	3.1	78	2	6	27	38	93	69	13	55
OKEOVER EAST	4.5	2.7	75	139	32	5	7	67	3	6	8
OKEOVER END	5.9	2.2	18	34	48	64	1	6	5	4	0
LANCELOT WEST	5.1	2.6	45	5	23	88	84	29	60	144	136
LANCELOT EAST	4.0	2.0	6	15	104	5	32	3	7	13	12
LANCELOT END	2.0	0.6	4	17	12	4	2	0	14	20	5
THEODOSIA OUTER	2.6	0.6	1	3	1	8	36	7	39	61	22
THEODOSIA INNER	5.0	2.2	3	4	1	7	5	4	3	17	11
MALASPINA WEST	7.2	2.9	56	55	17	24	46	100	31	54	50
MALASPINA EAST	7.2	2.9	37	11	49	13	39	17	39	43	25
DESOLATION OPEN	5.4	3.2	2	4	2	5	2	13	5	16	4
DESOLATION NORTH	4.4	2.6	117	18	41	63	11	12	4	19	16
TENEDOS BAY	6.6	4.0	24	12	2	4	12	17	0	28	9
DESOLATION SOUTH	4.3	2.6	39	17	2	2	0	22	1	16	5
GALLEY BAY	2.5	1.4	18	49	36	15	12	45	4	18	13
TOTAL	72.4	35.5	523	385	376	334	327	435	284	472	371

TABLE 1 (cont'd). Observations of Marbled Murrelets during boat surveys of the Okeover Inlet Study Area.

BLOCK	SEGMENT LENGTH (km)	SEGMENT AREA (sq km)	DATE AND TIME OF SURVEY 06 Jul am	07 Jul pm	10 Jul pm	12 Jul am	14 Jul am	18 Jul am	18 Jul pm	19 Jul am	19 Jul pm
OKEOVER WEST	5.1	3.1	31	117	89	33	38	48	35	68	22
OKEOVER EAST	4.5	2.7	36	10	89	8	6	71	62	5	10
OKEOVER END	5.9	2.2	6	5	43	59	64	14	29	7	0
LANCELOT WEST	5.1	2.6	264	66	146	0	6	49	26	23	60
LANCELOT EAST	4.0	2.0	25	13	24	6	4	42	68	18	3
LANCELOT END	2.0	0.6	27	9	5	1	4	10	24	5	8
THEODOSIA OUTER	2.6	0.6	103	53	20	11	5	50	53	51	30
THEODOSIA INNER	5.0	2.2	119	15	45	19	24	20	15	27	8
MALASPINA WEST	7.2	2.9	62	30	28	32	42	90	81	40	81
MALASPINA EAST	7.2	2.9	53	48	103	33	52	93	57	26	33
DESOLATION OPEN	5.4	3.2	4	15	3	2	6	7	2	4	0
DESOLATION NORTH	4.4	2.6	28	17	11	7	31	16	3	14	22
TENEDOS BAY	6.6	4.0	11	24	33	2	26	36	16	3	13
DESOLATION SOUTH	4.3	2.6	2	13	15	2	0	4	4	6	6
GALLEY BAY	2.5	1.4	27	4	23	0	5	4	5	9	20
TOTAL	72.4	35.5	798	439	677	215	313	554	480	306	316

TABLE 1 (cont'd). Observations of Marbled Murrelets during boat surveys of the Okeover Inlet Study Area.

BLOCK	SEGMENT LENGTH (km)	SEGMENT AREA (sq km)	DATE AND TIME OF SURVEY 20 Jul am	20 Jul pm	23 Jul am	23 Jul pm	24 Jul am	25 Jul am	28 Jul am	08 Aug am	08 Aug pm
OKEOVER WEST	5.1	3.1	52	26	3	0	10	5	0	0	1
OKEOVER EAST	4.5	2.7	12	4	5	2	2	0	0	1	2
OKEOVER END	5.9	2.2	4	5	0	3	0	0	0	0	1
LANCELOT WEST	5.1	2.6	17	58	3	6	38	11	0	16	5
LANCELOT EAST	4.0	2.0	12	13	2	2	7	7	3	4	2
LANCELOT END	2.0	0.6	2	11	0	17	1	6	1	1	1
THEODOSIA OUTER	2.6	0.6	67	28	6	32	13	13	25	1	2
THEODOSIA INNER	5.0	2.2	35	31	13	22	73	43	12	4	9
MALASPINA WEST	7.2	2.9	46	19	22	10	93	126	20	11	7
MALASPINA EAST	7.2	2.9	36	30	29	32	29	44	35	6	20
DESOLATION OPEN	5.4	3.2	3	1	1	1	6	12	10	20	27
DESOLATION NORTH	4.4	2.6	66	5	16	4	23	4	13	3	0
TENEDOS BAY	6.6	4.0	9	11	2	1	3	0	5	4	1
DESOLATION SOUTH	4.3	2.6	2	4	0	0	3	8	3	6	19
GALLEY BAY	2.5	1.4	14	3	5	0	13	27	31	9	4
TOTAL	72.4	35.5	377	249	107	132	314	306	158	86	101

TABLE 2. Ground counts of Marblet Murrelets from viewpoints southwest of the Okeover Inlet Study Area, June to August 1990.

SURVEY LOCATION	DATE OF COUNT						
	June 6	June 10	June 12	June 16	June 18	June 18	June 21
Dinner Rock	0	0	0	0	0	12	4
Emmond's Beach	0	0	0	7	2	10	0
Scuttle Bay	0	3	0	0	0	9	4
Gibson's Beach	32	13	1	7	3	5	9
Westview Lookout	13	3	0	0	0	3	38
Myrtle Beach	9	11	3	13	0	5	0
Brew Bay	11	7	5	0	0	0	2
Lang Bay Pier	12	3	3	7	0	0	1
McNair Road	1	3	1	6	0	1	0
Saltery Bay	0	3	0	7	4	0	4
TOTAL	78	46	13	47	9	45	62

TABLE 2 (cont'd). Ground counts of Marblet Murrelets from viewpoints southwest of the Okeover Inlet Study Area, June to August 1990.

SURVEY LOCATION	DATE OF COUNT								
	July 3	July 6	July 10	July 14	July 17	July 21	July 26	July 28	August 8
Dinner Rock	0	5	8	0	1	0	1	0	0
Emmond's Beach	5	7	5	7	4	9	0	4	0
Scuttle Bay	2	181	0	0	0	0	0	2	0
Gibson's Beach	0	21	11	4	0	1	3	4	0
Westview Lookout	2	54	2	4	0	3	0	0	5
Myrtle Beach	0	30	9	0	1	0	0	0	1
Brew Bay	0	36	21	9	0	9	0	6	0
Lang Bay Pier	3	27	0	2	0	11	0	0	0
McNair Road	2	9	6	0	0	0	0	0	0
Saltery Bay	3	6	9	1	2	19	0	16	7
TOTAL	17	376	71	27	8	52	4	32	13

APPENDIX 1: EXPERIMENTS IN CAPTURING MARBLED MURRELETS ON THE WATER WITH MIST-NETS

We tried three different methods of catching Marbled Murrelets in mist-nets: a) strings of nets suspended over the water on lines of floating poles, b) nets hung vertically beneath the surface, and c) nets floated flat on the surface.

Nets on floating poles

On 11 July 1990, we erected a set of nets on floating poles in Theodosia Inlet to observe the murrelet's response to nets and identify any technical problems. Theodosia Inlet has a narrow neck (100 m) that was frequently used by foraging murrelets. The precise location was only 3 or 4 m deep and we had seen 12 birds there, during the previous evening's survey.

We attached styrofoam floats (boat bumpers) and 2 kg weights to 5 m aluminum poles so that the poles would float vertically. We then anchored one pole and strung out 3 nets (17 m each) as though they were errected on land. There were no anchors on the middle poles but two anchors were required on the end poles to hold the array steady against the tidal current.

Deploying the array of nets, adjusting anchor lines, and acheiving sufficient tension in the nets took more than two hours. The nets stood from 1600 hrs to 2200 hrs during which time four murrelets swam within 3 m but no flying birds came within 50 m. Eight murrelets flew past on the other side of the inlet. During the same period there were 16 passes by boats (including a water taxi) and we decided that leaving the net array in place after dark would be a hazard. The tide also carried a fallen tree towards our nets and nearly carried them away. It would have been invisible in the dark.

We concluded that only nocturnal operations would be successful. Flying birds easily avoided the net array. The major problem with a floating array was the maintenance of tension during tide changes. We found that trying to keep tension through the nets themselves, was complicated and difficult, especially during deployment and if the anchors had to be moved. The poles need to be firmly anchored and tension maintained with a line connecting the tops. The nets can then be hung like individual curtains from that top line and are easily deployed or dismounted. Halibut poles, used to mark long-line fishing gear, appear ideal for this purpose (Fig. 1).

Using mist nets underwater

Throughout our surveys, we observed that the Marbled Murrelets most common response to approaching "threats" was to dive and swim away underwater. Flight was an uncommon response. We proposed to

take advantage of the diving response by deploying mist-nets in the water and urging birds towards them.

Between 8 and 16 July, we deployed nets in Lancelot and Theodosia Inlets near concentrations of foraging murrelets. Some of these nets hung vertically with corks on the top string and a few 5 gm split-shot weights on the lower. Other nets were floated on the surface with corks on both strings and bamboo poles at the ends. We deployed only two nets at a time to avoid drowning any birds and used two boats to slowly move the birds towards the nets.

Tidal currents carried the nets much further than we expected and the mist nets collected large numbers of jellyfish, small twigs, and pieces of kelp and other algae. We were unable to deploy the nets quickly because they became tangled and unmanageable when wet and the minimal disturbance created by deployment was sufficient to drive the murrelets far away. The murrelets would not be herded. They dispersed in front of the boats and dived away if pressed beyond their preferred location.

It may be possible to use submerged nets to catch murrelets but mist-nets are probably too fragile and too susceptible to entanglement. It also seems unlikely that a large enough array of submerged nets can be deployed in most inlets. Lancelot Inlet is about 800 m across and the largest mist-nets only 17 m. Biologists in Washington propose to pursue murrelets with a towed monofilament net (8 m by 20 m, 18 cm mesh) (E. Cummings pers. comm.). This active approach should circumvent most of the problems in the passive use of submerged mist-nets.

Recommendations

The passive use of mist-nets below the water surface seems too clumsy and ineffective to develop into a usable capture technique. There are,however, three methods of capture that need further study and could be tested in the coming field season: a) aerial arrays of mist-nets, b) towed underwater nets, c) the hand-held net launcher or capture gun. All three could develop into the reliable methods of capture-at-will needed for telemetry projects.